



# Aviation Weather Routing Tool: A Decision Aid for Manned/Unmanned Aircraft Routing



***TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.***

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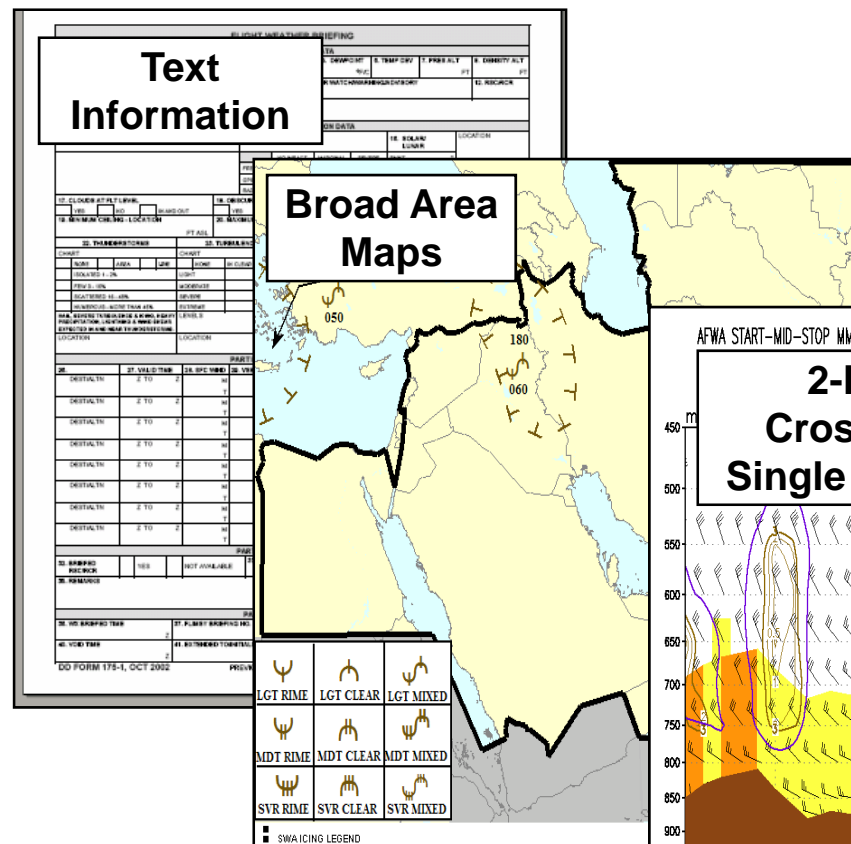
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# The Requirement

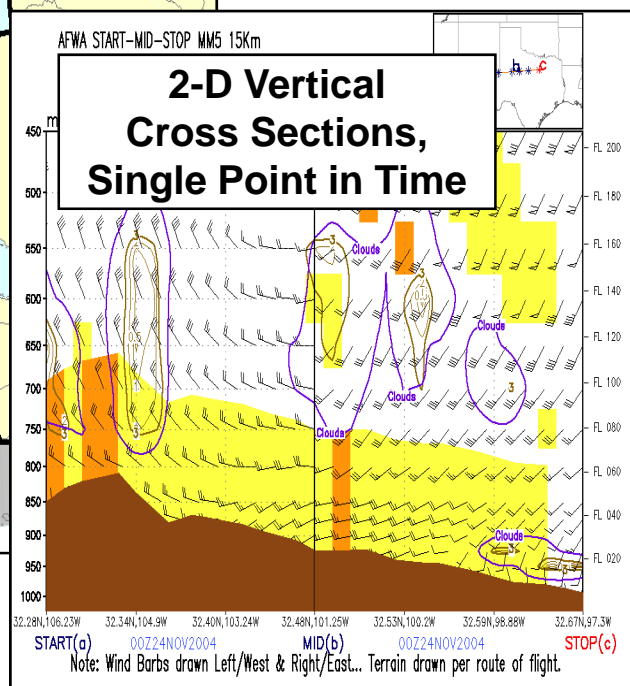


## What the User Currently Receives



## What the User Must Decide

- Are the mission waypoints/altitudes OK?
- How might the weather situation change?
- How will the vehicle and its sensors be affected?



## What the User Needs

**An Automated Route Optimization System**

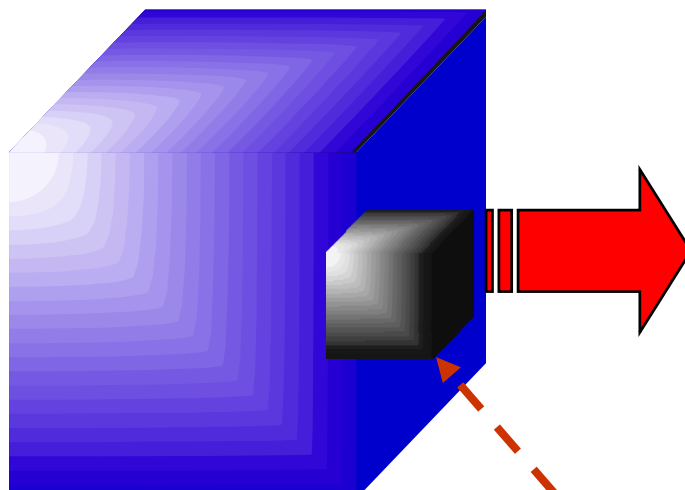
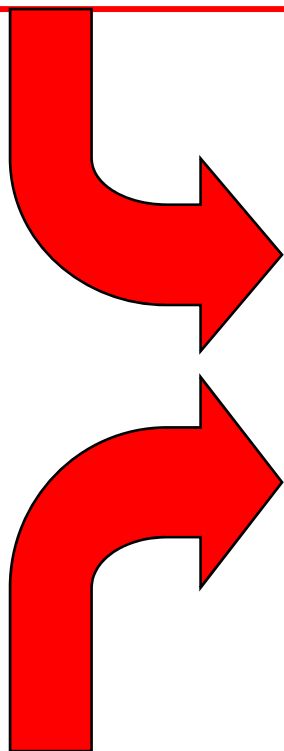
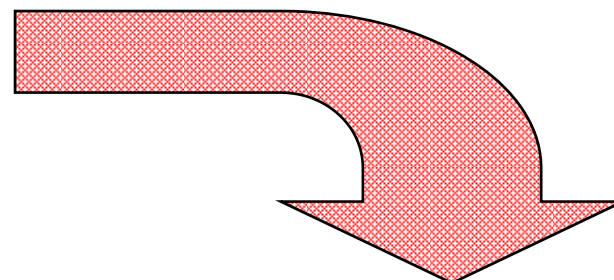
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# GENERAL SUPPORT CONCEPT



Theater-scale forecast model database...  
“Weather Data Cube”  
→ 4-D gridded fields of weather parameters



Weather Decision  
Aid Products for manual and  
automated applications.

Nesting → Nowcast 0-3hr Database.  
Automated refresh of forecast 4-D  
cube for pre-mission & enroute updates.

**LOCAL SENSORS**  
Surface Data Sensors  
Upper-Air Sensors  
*Aircraft MET Sensors*

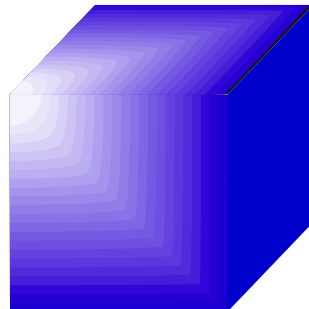
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# “Optimized” Flight Path Aviation Weather Routing Tool (AWRT)



**New** 4-D Weather  
Forecast Grid



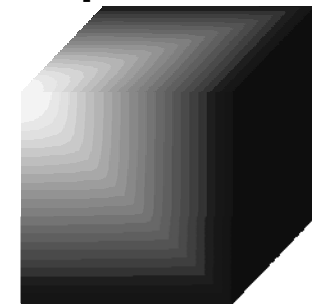
+

**Aircraft-Specific  
Weather Impacts  
Threshold Rules**

*(from Tri-Service  
Integrated Weather  
Effects Decision Aid (T-  
IWEDA) database)*

=

4-D Weather  
Impacts Grid



+

**Altered Flt Path (if needed)**

**Initial/Current  
Flight Path**

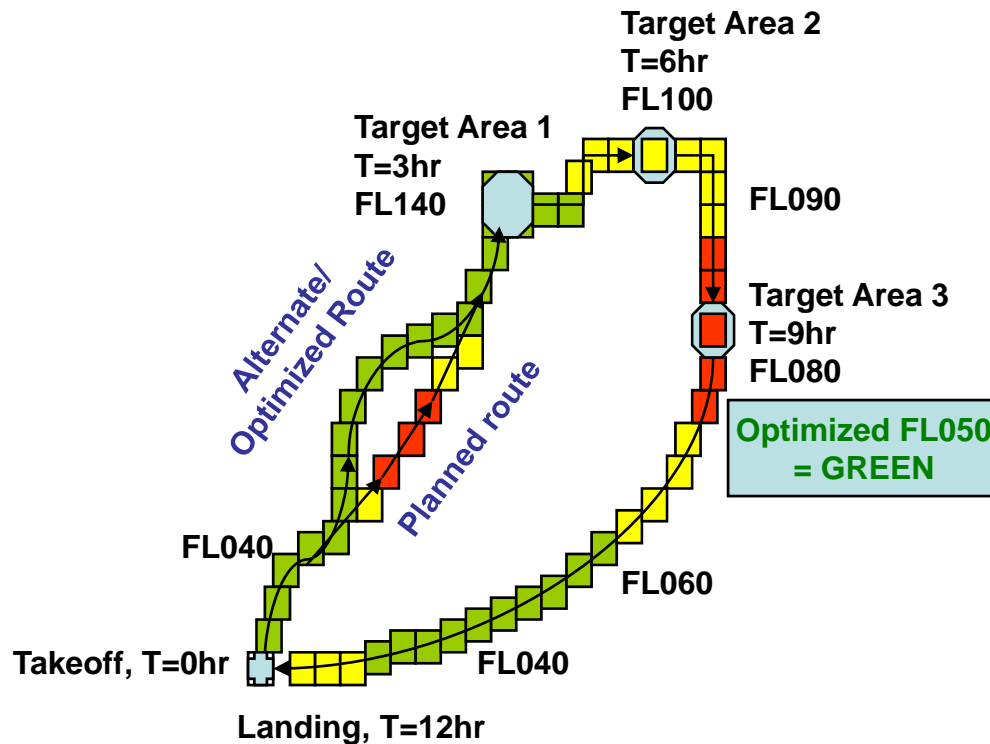
**New Flt Path Options;  
Avoiding Enrte Hazards**

**PATH  
OPTIMIZATION**

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# “Optimized” Flight Path Aviation Weather Routing Tool (AWRT)



- *Original planned flight path routes through “red” or “unfavorable” conditions*
- *Automated flight route optimization algorithms to provide alternate routes around, over, under unfavorable conditions*
- *Look for the “greenest” or “most favorable” path*
- *Solution is an “all-weather” routing option to increase mission success rates.*
- *Technology applicable to ALL aircraft*



## AWRT Development: Adapting the A\* Routing Algorithm



- Computes the “Lowest Cost” path between points.
- Cost function can represent fuel consumption, hazard to the aircraft, mission constraints, etc.
- Searches out from a starting point, storing partial paths after each step.
- The partial paths are stored in a prioritized list.
- A Cost Function then determines the “Lowest Cost” of the paths in the priority list.
- A\* is guaranteed to find a lowest cost path and is usually computationally cheaper than an exhaustive (or breadth first) search.



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# A\* on a 2-D Grid



A\* Demonstration - Microsoft Internet Explorer

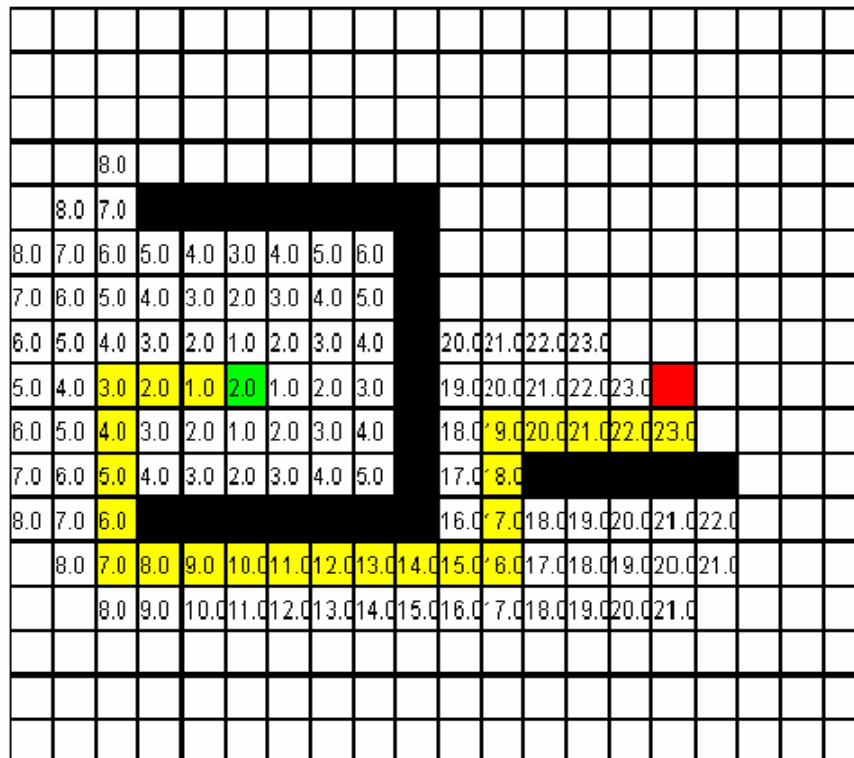
File Edit View Favorites Tools Help

Back Forward Stop Home Search Favorites

Address <http://www.vision.ee.ethz.ch/~buc/astar/AStar.html>

## A\* Demonstration

Load Map:  Method: Classic A\*



☒ set blocks

Impossible

☐ set start

☐ set finish

### Key

- Start Point
- End Point
- Tough
- V.Tough
- Impossible
- Easy
- Route

30

Applet AStarApplet started

Internet

start

Inbox ...

3 Mic...

Micros...

3 Int...

Micros...

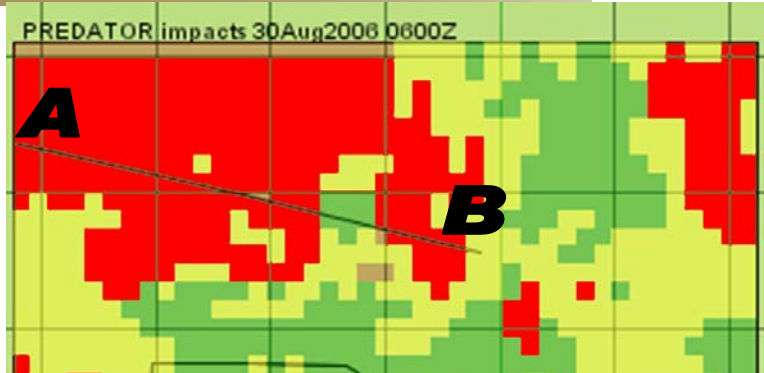
Internet

2:47 PM



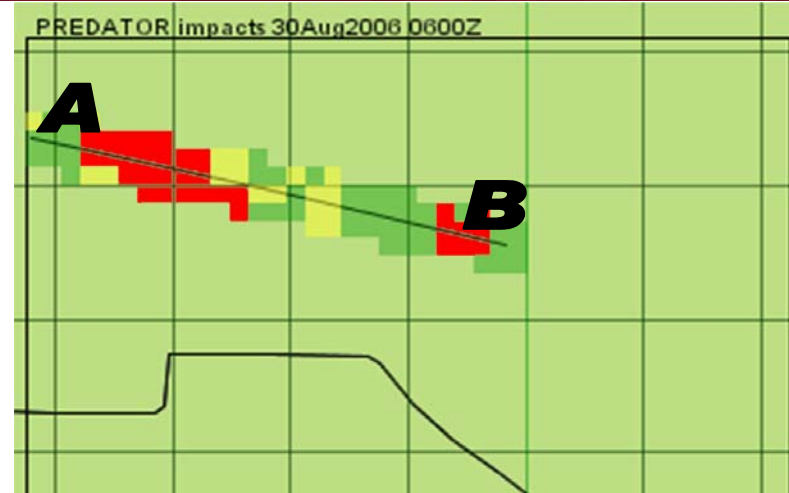


# Applying A\* to Flight Route Optimization

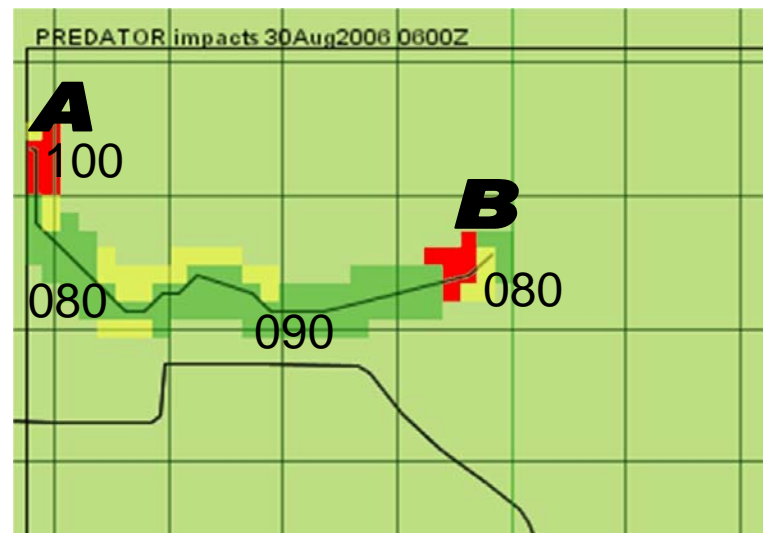


Worst conditions shown for all altitudes

Planned route from A to B at FL100 passes through unfavorable conditions



Worst Conditions at FL100 (+/- 500')

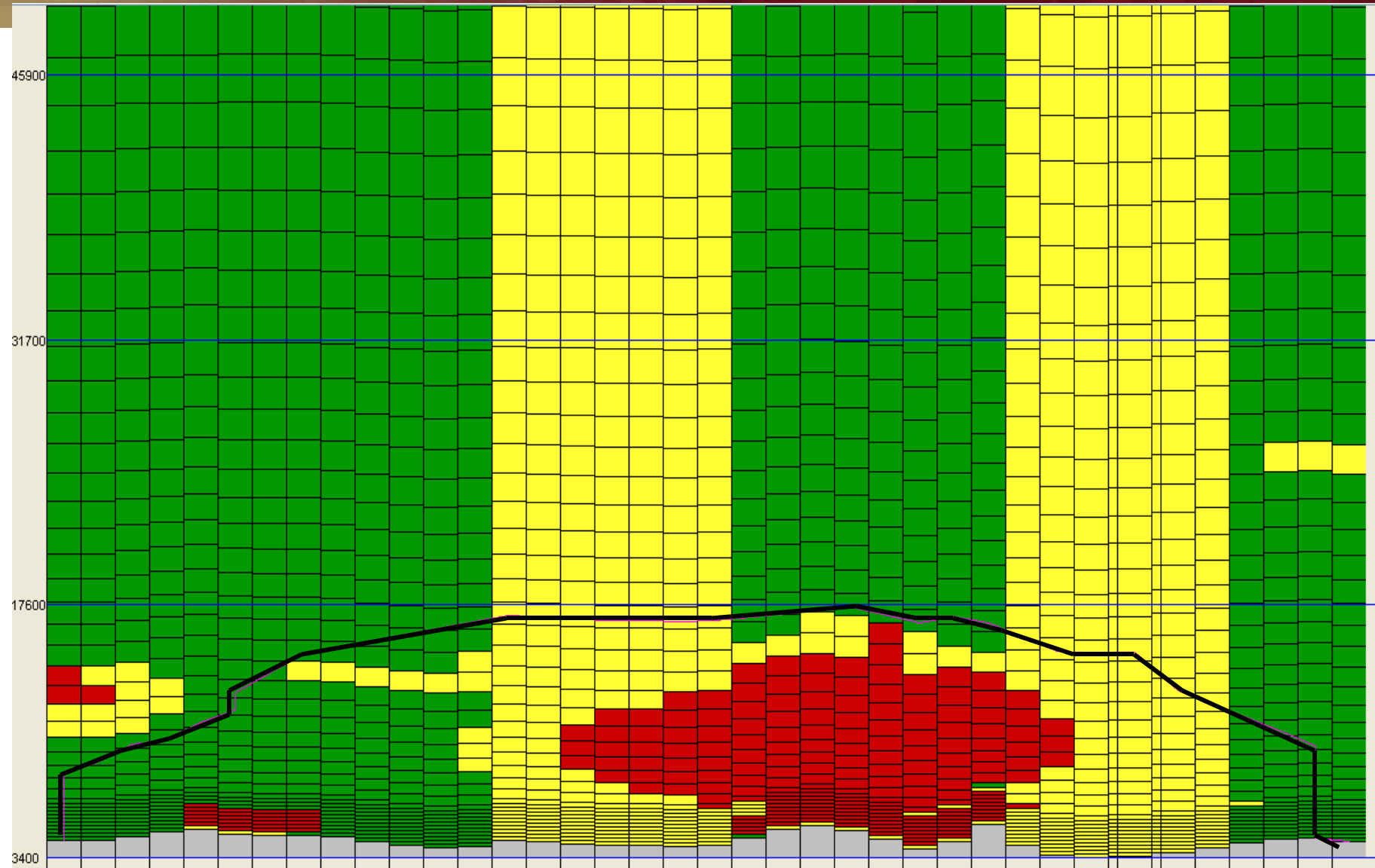


Optimized route at varying FLs

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# Optimized Vertical Slice



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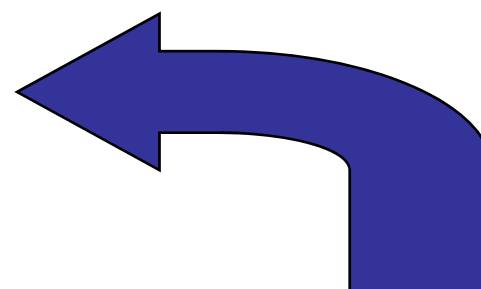
# Potential AWRT Operational Fielding Concepts



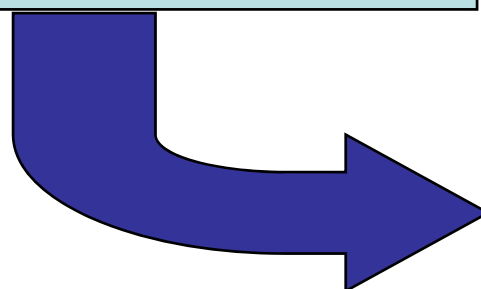
## 1. Web-Enabled/Net-Centric (Thin Client)

**AWRT Server – access to 4-D Weather data cube:**

1. Receives route request
2. Calculates weather effects data cube based on aircraft & restrictions
3. Meshes route with weather effects data cube
4. Derives initial weather effects on route
5. Calculates AWRT optimized route options
6. Creates display and A/N output of route options
7. Data and display available to Operator/Planner/GCS/M2M to Aircraft



Via web page interface, enter:  
-Aircraft info  
-Route waypoints & altitudes  
-Enter restrictions  
-Send request



Operator/Planner/GCS:  
PC/Laptop with  
SIPRNET/NIPRNET connectivity

TEC



## 2. Autonomous (Local) Capability (Thick Client)

Operator/Planner/JMPS/GCS/??:

**Server/PC/Laptop hosts**

1. Comm. connectivity to ingest 4-D Weather Grids
2. Weather Effects Grid Creator
3. AWRT Route Optimization capability
4. A/N & graphics output of route options

**4-D Weather Forecast Data Cube:**  
**DCGS-A Weather**  
**Regional/Theater Forecast Center**  
**AF Weather Agency**

- Calculates weather effects data cube based on aircraft & restrictions
- Meshes route with weather effects data cube
- Derives initial weather effects on route
- Calculates AWRT optimized route options
- Creates local display and A/N output of route options/M2M to Aircraft



# AWRT DEMO





# Select Asset(s) from List:



Tri-Service IWEDA

File Edit Screen Help

List Hierarchy Selected

No special condition

Selected Assets

Scan Eagle UAS

Map Asset Info

1:2,250,000

**User Selected Asset List (ScanEagle UAS)**

**Available Asset List**

Select

Add WEM Save

Forecasts Subdomains

Planning

Current Ops

180ct2007 0000Z

180ct2007 0300Z

180ct2007 0600Z

180ct2007 0900Z

180ct2007 1200Z

180ct2007 1500Z

180ct2007 1800Z

180ct2007 2100Z

190ct2007 0000Z

190ct2007 0300Z

190ct2007 0600Z

190ct2007 0900Z

190ct2007 1200Z

190ct2007 1500Z

190ct2007 1800Z

Select All

Deselect All

Recenter

Refresh

**Available Forecast Times (all selected)**

Lat, Lon (33.356, -114.078) - x, y (288,347)





# Compute Weather Effects Matrix:



**Tri-Service IWEDA**

File Edit Screen Help

List Hierarchy Selected

No special condition

Selected Assets

Scan Eagle UAS

Map Asset Info Impact Levels

1:2,250,000

**Geospatial Area of Interest (AOI):**

**Compute Weather Effects Matrix (WEM) button**

TPQ-36

TPQ-37

Select

Add WEM Save

Forecasts Subdomains

Planning

Current Ops

18Oct2007 0000Z

18Oct2007 0300Z

18Oct2007 0600Z

18Oct2007 0900Z

18Oct2007 1200Z

18Oct2007 1500Z

18Oct2007 1800Z

18Oct2007 2100Z

19Oct2007 0000Z

19Oct2007 0300Z

19Oct2007 0600Z

19Oct2007 0900Z

19Oct2007 1200Z

19Oct2007 1500Z

19Oct2007 1800Z

Select All

Deselect All

Recenter

Refresh

**ScanEagle color coded WEM over forecast times (red=unfavorable, amber=marginal impacts)**

Lat, Lon (32.407, -115.35) - x, y (3,638)

WEM

Name	18/0000	18/0300	18/0600	18/0900	18/1200	18/1500	18/1800	18/2100	19/0000	19/0300
Selected Assets	R	R	R	R	R	R	R	R	R	R
Scan Eagle UAS	R	R	R	R	R	R	R	R	R	R





# View ScanEagle Impacts over AOI:



Tri-Service IWEDA

File Edit Screen Help

List Hierarchy

- SOF AIRDROP/EQUIP
- SOF AWADS
- SOF CAS
- SOF COMM
- SOF EO/IR
- SOF GROUND
- SOF HELO
- SOF MARITIME
- SOF MFF
- SOF NBC
- SOF PSYOPS
- SOF RECON/SURV
- SOF STEERABLE/CHUTE
- STINGER-AIRBORNE
- STINGER-GROUND
- Scan Eagle UAS
- TACTICAL AIRLIFT OPS
- TLQ-17A
- TOW-AIRBORNE
- TOW-GROUND
- TOW2-AIRBORNE
- TOW2-GROUND
- TPQ-36
- TPQ-37

Select

Add WEM Save

Forecasts Subdomains

Planning

Current Ops

18Oct2007 0000Z

18Oct2007 0300Z

18Oct2007 0600Z

18Oct2007 0900Z

18Oct2007 1200Z

18Oct2007 1500Z

18Oct2007 1800Z

18Oct2007 2100Z

19Oct2007 0000Z

19Oct2007 0300Z

19Oct2007 0600Z

19Oct2007 0900Z

19Oct2007 1200Z

19Oct2007 1500Z

19Oct2007 1800Z

Select All

Deselect All

Recenter

Refresh

Map Asset Info Impact Levels

1:2,250,000

Selected Assets

Scan Eagle UAS

Geospatial impacts at 1200 GMT on the 18th

Lat, Lon (34.338, -112.269) - x, y (772,1)

Name	18/0000	18/0300	18/0600	18/0900	18/1200	18/1500	18/1800	18/2100	19/0000	19/0300
Selected Assets	R	R	R	R	R	R	R	R	R	R
Scan Eagle UAS	R	R	R	R	R	R	R	R	R	R





# Define the Flight Path (FP):



Tri-Service IWEDA

File Edit Screen Help

List Hierarchy Selected No special condition Selected Assets

Map Asset Info Impact Levels 1:2,250,000

Edit Subdomain "New Flight Path Subdomain"

Subdomain Name ScanEagle2

Border Color

Area Assets

Takeoff/Way Points

Stop Map Input Clear

Lat:	32.707	Alt:	<input type="checkbox"/> All	feet
Lon:	-114.657			
Lat:	33.459	Alt:	<input type="checkbox"/> All	feet
Lon:	-112.814			

Waypoints/times are entered via map clicks (or manually) – M2M in future release

Begin

End

AGL MSL

Time Sensitive

Commit Cancel

Lat, Lon (33.135, -113.146) - x, y (553,451)

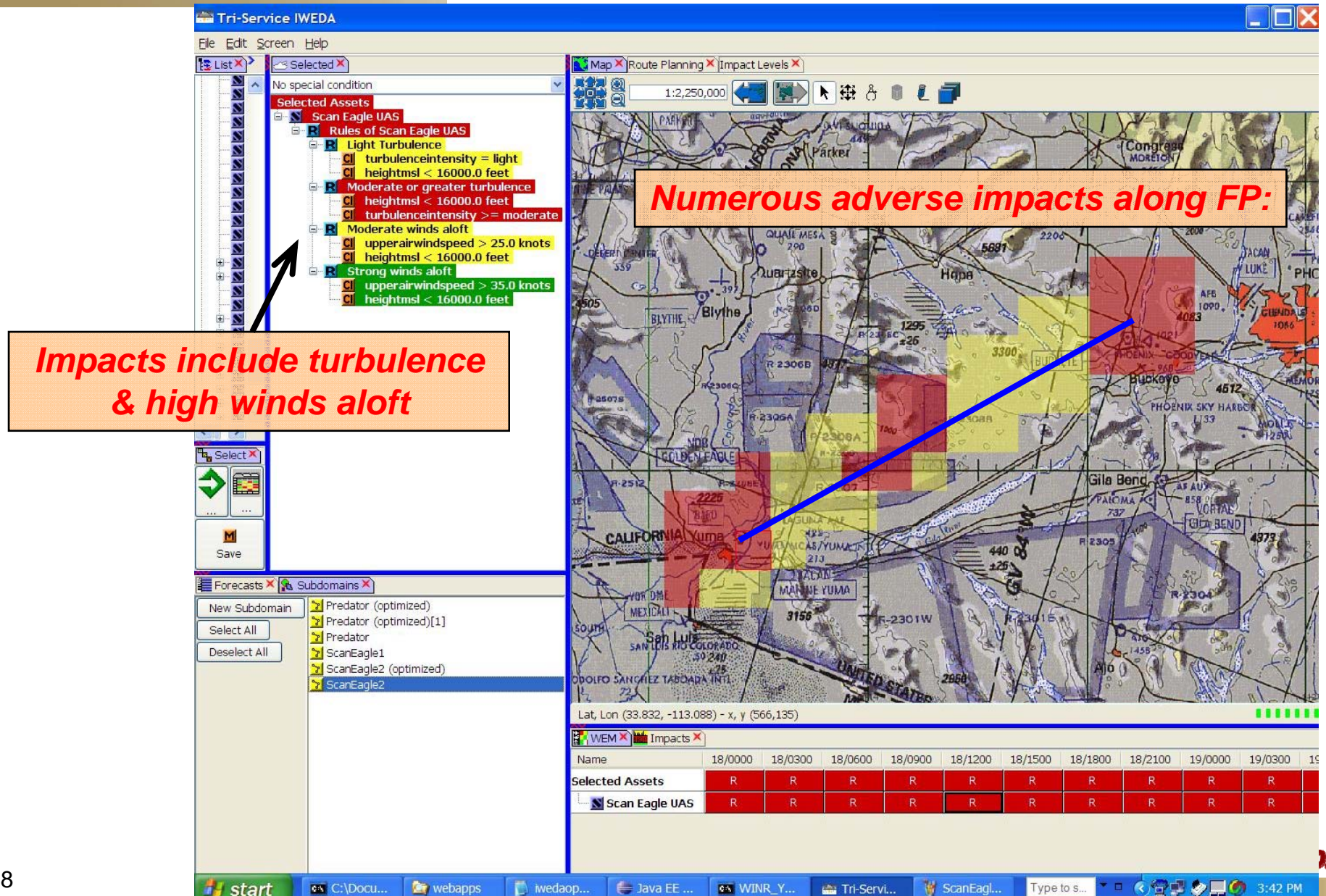
WEM Impacts

Name	18/0000	18/0300	18/0600	18/0900	18/1200	18/1500	18/1800	18/2100	19/0000	19/0300
------	---------	---------	---------	---------	---------	---------	---------	---------	---------	---------



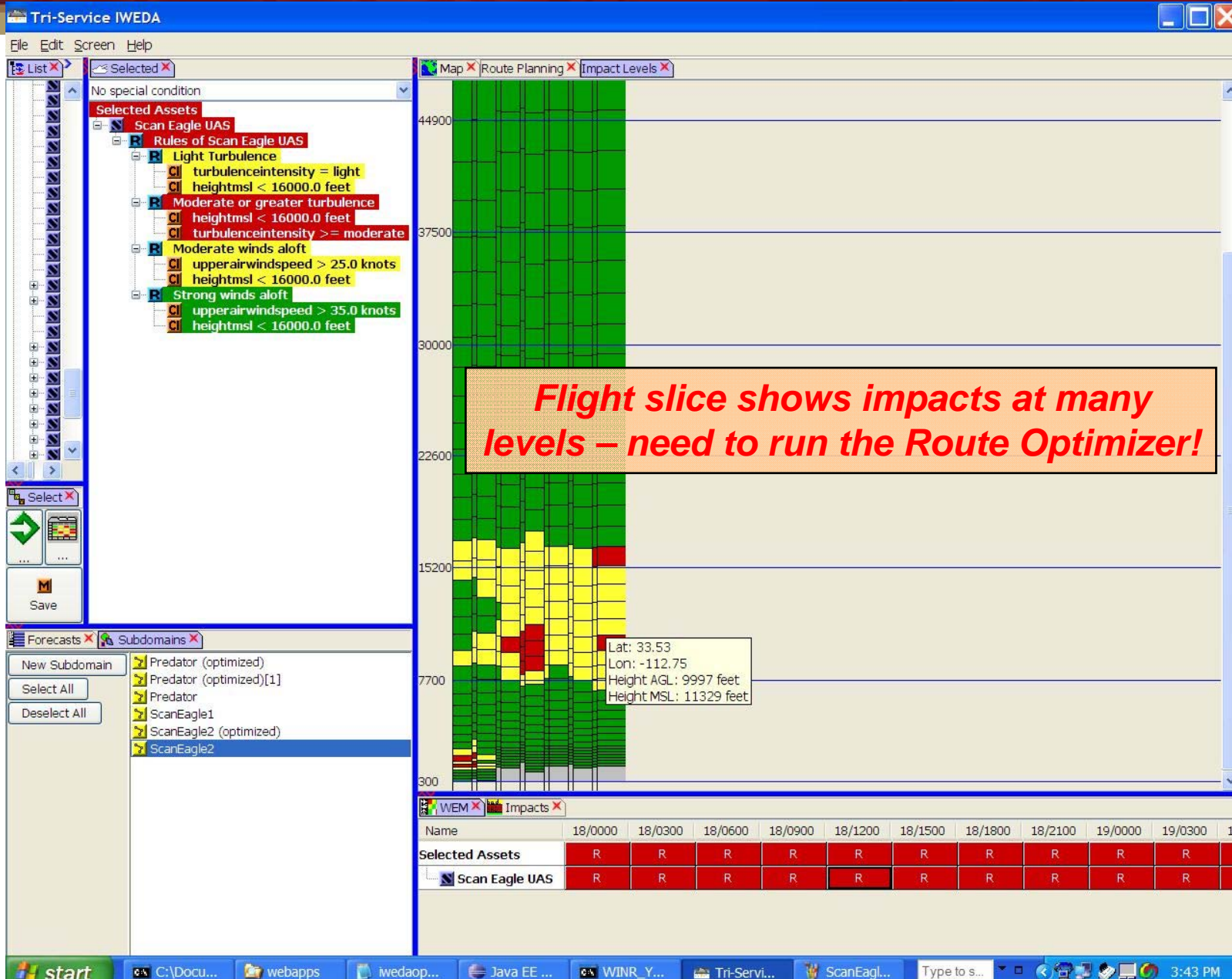


# Compute & View Impacts over FP:





# Flight Slice along Path:







# Route Planning Specifics:



Tri-Service IWEDA

File Edit Screen Help

List Selected Map Asset Info Route Planning Impact Levels

Route Planning

No special condition

Selected Assets

- Scan Eagle UAS
- Rules of Scan Eagle UAS
  - Light Turbulence
    - turbulenceintensity = light
    - heightmsl < 16000.0 feet
  - Moderate or greater turbulence
    - heightmsl < 16000.0 feet
    - turbulenceintensity >= moderate
  - Moderate winds aloft
    - upperairwindspeed > 25.0
    - heightmsl < 16000.0 feet
  - Strong winds aloft
    - upperairwindspeed > 25.0
    - heightmsl < 16000.0 feet

Low 0 1000 2000 3000 4000 5000 Feet MSL AGL

High 0 1000 2000 3000 4000 5000 Feet MSL AGL

Beginning Time 18 October 2007 11 00

Speed 100 Knots

Execute

WEM Impacts

Name	18/0000	18/0300	18/0600	18/0900	18/1200	18/1500	18/1800	18/2100	19/0000	19/0300
Selected Assets	R	R	R	R	R	R	R	R	R	R
Scan Eagle UAS	R	R	R	R	R	R	R	R	R	R

**ScanEagle max ceiling and speed along with begin time and risk tolerance are set here**



# Optimized FP Results:



**Optimized flight path waypoints  
& times are viewable:**

**Optimized route avoids all  
adverse weather!**

Tri-Service IWEDA

File Edit Screen Help

List Selected Map Route Planning Impact Levels

No special condition 1:2,250,000

Edit Subdomain "ScanEagle2 (optimized)"

Subdomain Name ScanEagle2 (optimized)

Get From Map Clear

Lat:	32.759	Alt:	<input checked="" type="checkbox"/> 295.276	feet
Lon:	-114.611			
Lat:	32.726	Alt:	<input checked="" type="checkbox"/> 770.672	feet
Lon:	-114.039			
Lat:	32.726	Alt:	<input checked="" type="checkbox"/> 961.739	feet
Lon:	-113.877			
Lat:	32.996	Alt:	<input checked="" type="checkbox"/> 1,417.516	feet
Lon:	-113.554			
Lat:	33.131	Alt:	<input checked="" type="checkbox"/> 1,464.675	feet
Lon:	-113.393			
Lat:	33.131	Alt:	<input checked="" type="checkbox"/> 1,562.648	feet
Lon:	-113.232			
Lat:	33.4	Alt:	<input checked="" type="checkbox"/> 1,366.165	feet
Lon:	-112.909			
Lat:	33.51	Alt:	<input checked="" type="checkbox"/> 1,332.021	feet
Lon:	-112.82			

☐ AGL ☒ MSL

☒ Time Sensitive

Commit Cancel

Map Route Planning Impact Levels

3.837 - x, y (379,0)

WEM Impacts Forecast Data

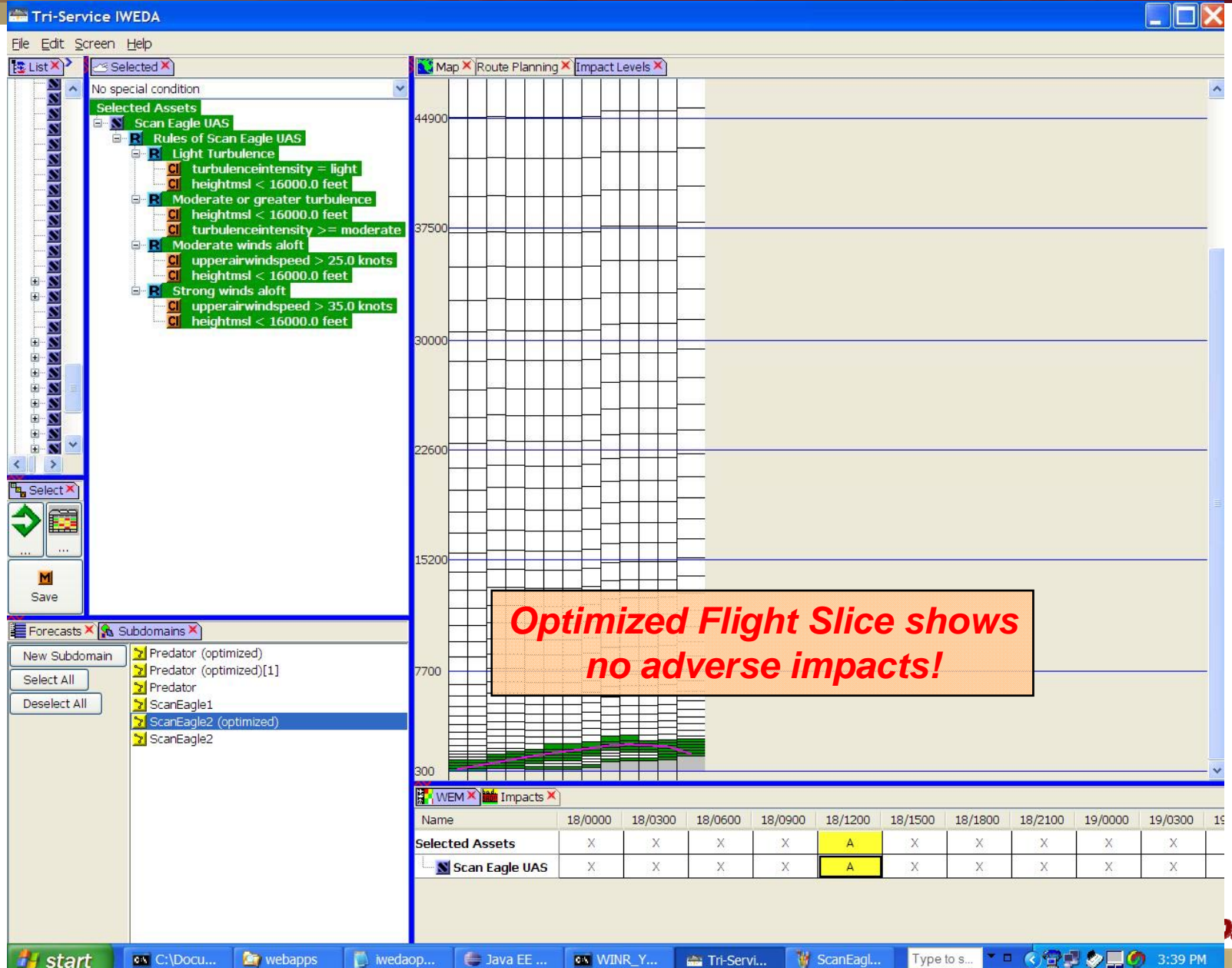
Name	18/0000	18/0300	18/0600	18/0900	18/1200	18/1500	18/1800	18/2100	19/0000	19/0300	19/0600
Selected Assets	X	X	X	X	A	X	X	X	X	X	X
Scan Eagle UAS	X	X	X	X	A	X	X	X	X	X	X

start C:\Docume... webapps iwedaopen... Java EE - tsL... WINR\_YPG Tri-Service L... Type to s... 3:49 PM





# Flight Slice along Optimized Path:

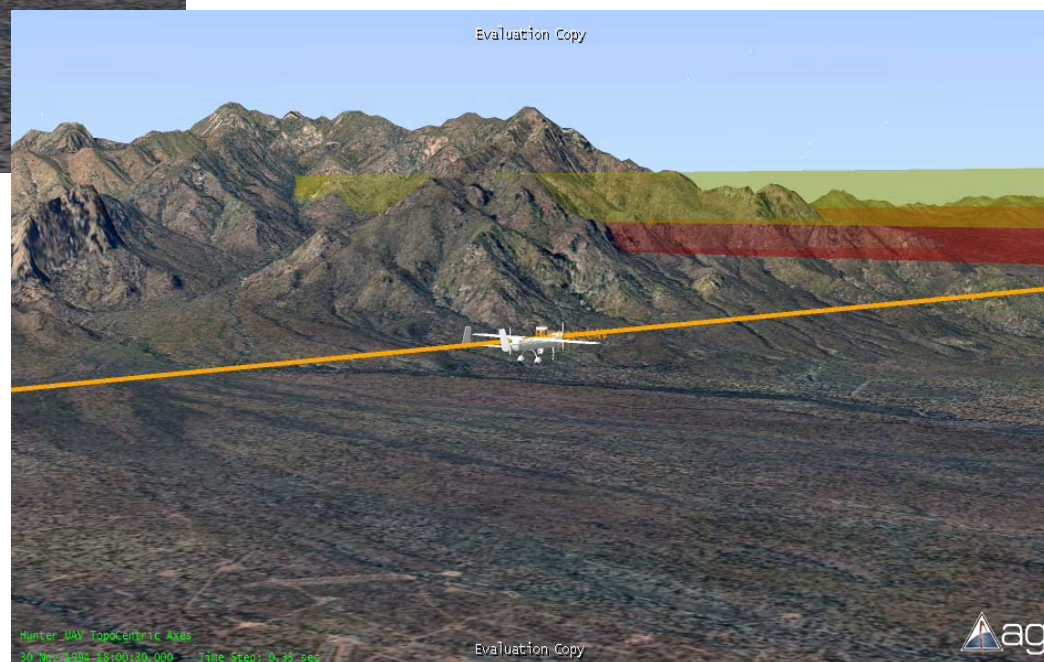




# AWRT Visualization: Satellite Took Kit (STK) Visualization Software



**UAS flight through unfavorable weather conditions (depicted in red) such as Severe Turbulence**



**Optimized flight route, automatically routed UNDER the hazardous weather levels.**

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# CAPABILITIES: Current and Future



## CURRENT:

- PC-based & IMETS/DCGS-A Hosted
- Hard-wired to T-IWEDA
- Map GUI = Open Map
- User input of route and flight levels
- Routing rules (cost functions) include:
  - Weather hazards
  - Air speed
  - Head wind component
  - Forecast periods corresponding to flight times

**QUESTIONS???**  
**COMMENTS???**

## FUTURE:

- Browser version
- Platform independent
- JAAWIN-hosted (Experimental use)
- No-fly zones/restricted airspace considered in routing calculations
- Multiple route options (associated with varied risk levels) displayed or toggled
- Multiple missions displayed at once or toggled
- Automated weather data/flight plan ingest
- Machine-to-Machine capabilities
- Live enroute updates as often as weather data cube updates
- Visualizations: Satellite Tool Kit (STK), FalconView, Google Earth, others?
- **USER INPUT FOR OTHER IDEAS???**

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